Report No. NAWCADWAR-93015-60

AIRCRAFT CARRIER EXPOSURE TESTS OF CAST MAGNESIUM ALLOYS

Joseph Kozol and Edwin Tankins
Air Vehicle and Crew Systems Technology Department (Code 6063)
NAVAL AIR WARFARE CENTER
AIRCRAFT DIVISION WARMINSTER
P.O. Box 5152
Warminster, PA 18974-0591

1 MARCH 1993

FINAL REPORT

Approved for Public Release; Distribution is Unlimited.

Prepared for
NAVY EXPLORATORY DEVELOPMENT PROGRAM
AIRCRAFT MATERIALS BLOCK, NA2A

NOTICES

REPORT NUMBERING SYSTEM — The numbering of technical project reports issued by the Naval Air Warfare Center, Aircraft Division, Warminster is arranged for specific identification purposes. Each number consists of the Center acronym, the calendar year in which the number was assigned, the sequence number of the report within the specific calendar year, and the official 2-digit correspondence code of the Functional Department responsible for the report. For example: Report No. NAWCADWAR-92001-60 indicates the first Center report for the year 1992 and prepared by the Air Vehicle and Crew Systems Technology Department. The numerical codes are as follows:

CODE	OFFICE OR DEPARTMENT
00	Commanding Officer, NAWCADWAR
01	Technical Director, NAWCADWAR
05	Computer Department
10	AntiSubmarine Warfare Systems Department
20	Tactical Air Systems Department
30	Warfare Systems Analysis Department
50	Mission Avionics Technology Department
60	Air Vehicle & Crew Systems Technology Department
70	Systems & Software Technology Department
80	Engineering Support Group
90	Test & Evaluation Group

PRODUCT ENDORSEMENT — The discussion or instructions concerning commercial products herein do not constitute an endorsement by the Government nor do they convey or imply the license or right to use such products.

Reviewed By: J. Waldman — **Date:** 20 May 1993
Branch Head

Reviewed By: [signature] — **Date:** 14 June 1993
Division Head

Reviewed By: Gerald P. [illegible] — **Date:** 17 June 1993
Director/Deputy Director

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	1 March 1993	Final

4. TITLE AND SUBTITLE

Aircraft Carrier Exposure Tests of Cast Magnesium Alloys

5. FUNDING NUMBERS

6. AUTHOR(S)

Joseph Kozol and Edwin Tankins

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Vehicle and Crew Systems Technology Department (Code 6063)
Naval Air Warfare Center
P.O. Box 5152
Warminster, PA 18974-0591

8. PERFORMING ORGANIZATION REPORT NUMBER

NAWCADWAR-93015-60

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Navy Exploratory Development Program
Aircraft Materials Block, NA2A

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for Public Release; Distribution is Unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report describes the results of an ongoing effort to determine the behavior of aircraft materials and finishes in the Naval environment of aircraft carrier flight decks. Coated cast magnesium alloys were exposed to the carrier environment for a relatively short time and experienced significant corrosion effects compared to aluminum control specimens.

14. SUBJECT TERMS

Magnesium Alloys, Exfoliation, Aircraft Carrier Environment

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The corrosive degradation of aircraft materials experienced by Naval aircraft in the aircraft carrier operating environment is of great interest to the Navy. The corrosive environment of aircraft aboard carriers deployed in the Western Pacific and the Indian Ocean is far more severe than in other industrial and marine environments (Ref 1). The environment includes jet engine exhaust products as well as salt sea spray, high temperatures and high humidity. The corrosion behavior of materials intended for application on present and future Naval aircraft is being determined. As part of this effort, a variety of aircraft materials and finishes are being exposed in the Naval environment of aircraft carrier flight decks.

This report describes the effects of four months of exposure testing on coated cast magnesium alloys aboard the USS Ranger, during deployment to the Western Pacific and the Persian Gulf. During this short-term deployment, the overall exposure experienced by the aluminum control specimens was not severe. However the magnesium alloys experienced significant corrosion effects, which are described in this report.

EXPOSURE CONDITIONS

EXPOSURE RACK

The rack face was made of expanded steel mesh which was cadmium plated, chromate conversion coated, and painted with MIL-P-23377 epoxy primer and MIL-C-81733 polyurethane topcoat. Specimens were insulated from the rack face by nylon washers and were fastened to the rack face with nylon bolts and nuts. MIL-A-46146 silicone rubber sealant was applied in the bolt holes of the specimens and under the bolt heads to prevent crevice corrosion. Specimens were exposed at a 45-degree angle to the vertical.

WEATHER CONDITIONS

Weather reports were collected from hourly observations made by ship personnel on Form CNOC 3140/8. From these reports, daily observations at 1200 hrs. and 2400 hrs. were recorded for atmospheric temperature, dew point, relative humidity, wind speed and sky cover. Table I shows the weekly averages for the atmospheric

conditions. It is reported that temperatures at the carrier deck level can reach as high as 140°F(60°C), significantly greater than that of the ambient air.

TEST MATERIALS

ALUMINUM ALLOY CONTROL SPECIMENS

One inch thick aluminum alloy 7075 T651 plate was machined into step specimens to expose the T/10 plane, with one tenth of the thickness removed, and the T/2 plane, with one half of the thickness removed. One step specimen was overaged to the T73 temper by heating for 24 hrs at 120°C (350°F), according to the Military Specification for Heat Treatment of Aluminum Alloys, MIL-H-6088F. The aluminum alloy exfoliation control specimens were prepared as follows:

1. Degrease
2. Etch in 5% NaOH at 80°C (176°F), 3 min.
3. Rinse
4. Desmut in conc. HNO_3, 30 sec.
5. Rinse in deionized water
6. Dry in oil free air

MAGNESIUM TEST PANELS

Magnesium block test panels were anodized, coated and provided by General Electric Co. Preparation and identification of the alloys are shown in Table II. The center hole was utilized to support the panels during application of the HAE anodize and required touch-up prior to resin application. The WE43 alloy panels were touched-up with Alodyne 1200 (MIL-C-5541) and the QE22 alloy panels with Dow 19. The epoxy resin sealer was applied at the GEAE Quality Engineering Laboratory by GE personnel.

Inco 718 bolts, A-286 nuts and aluminum (A356) blocks were provided with the test panels to test the effects of contact with dissimilar materials. A masked off area around the center hole, was not painted on the unsealed QE22 and sealed WE43 panels. This area was the surface where the aluminum blocks interfaced. The

appearance of the magnesium alloy test specimens prior to shipboard exposure is shown in Figure 1 (second from the right) and Figure 2 (second from the left). Note the aluminum blocks attached to the top and bottom specimens. From top to bottom, the specimens are DF1471-3, DF1440-1, DF1312-3 (Figure 1) and DF1312-4, DF1440-2, DF1471-4 (Figure 2). Specimens 1312 are WE-43 magnesium alloy and specimens 1471 and 1440 are QE-22.

RESULTS AND DISCUSSION

All shipboard exposed specimens were covered with a thin, gray film upon return. The analysis of similiar films, from previous exposures, indicated the film consisted primarily of MIL-L-23699 engine oil deposits with some sulfur (Ref 3). The results of the shipboard exposure tests are given in Table III. There was a small but noticeable amount of exfoliation on the T/2 plane of the 7075-T651 specimen. This was to be expected because the environmental exfoliation conditions were less severe than previous deployments and the exposure time was shorter than for other deployments (Ref 3). By comparison, the 7075T73 control showed only a small amount of pitting and general corrosion, demonstrating the improved corrosion resistance of the overaged (T73) condition. The important indications from the magnesium blocks were that even for a relatively mild exposure, the unprotected areas showed severe corrosion.

The appearance of the magnesium blocks after exposure may be seen in Figures 3 and 4, in the same relative positions shown in Figures 1 and 2. General corrosion through the coating is shown in Figure 5, with severe attack along the scribe marks of the unsealed specimen DF 1471-3. Attack on the unsealed area and galvanic attack under the aluminum block is also seen on this specimen, shown in Figure 6. The same alloy with epoxy resin seal and glyptal was not corroded, except in the scribe marks, shown in Figure 7.

It appears that both cast magnesium alloys (QE-22 and WE-43) must have a sound epoxy resin surface seal even though anodized and painted, in order to avoid corrosive attack. Any damage to the coating results in rapid corrosion, even during a relatively mild deployment.

CONCLUSIONS

1. Magnesium alloys QE-22 and WE-43 experience rapid corrosion in the carrier environment.

2. Magnesium alloys must be sealed and coated to avoid corrosion damage. Any damage to the coating will result in severe corrosion attack even for short deployment duration.

3. The 7075 T6 aluminum alloy (peak aged) shows some exfoliation starting on mid plane. The 7075 T73 (over aged) shows no exfoliation.

REFERENCES

1. E.J. Jankowsky and S.J. Ketcham, "Shipboard Exposure Testing", NADC 81075-60, 1981.

2. Surface Sealing of Magnesium Alloy Components, 200A, Magnesium Elektron inc., Flemington, NJ.

3. J.J. Thompson, Shipboard Exposure Testing of Aircraft Material Aboard USS Constellation (Feb - Sept 1985); Report No. NADC-87125-60, Sept 1987.

ACKNOWLEDGMENTS

Funding for this program was provided by the 6.2 Aircraft Materials Block (NA2A).

The authors wish to acknowledge the assistance of Mr. Robert Mahorter, NAWCAD Trenton for coordinating the effort with General Electric Co. to provide the magnesium test specimens for shipboard exposure.

Table I. Atmospheric Conditions — Weekly Averages.

Week	Atmos. Temp °C	Dew Pt. °C	Relative Humidity	Average* Sky Cover	Average Wind Speed (Knots)
1	25	22.8	87	8	22
2	27.2	22.2	74	8	16
3	23.3	15.6	62	7	14
4	22.2	18.6	81	6.5	11
5	22.2	17.2	73	8	18
6	21	15	68.6	9	14
7	18.6	9.05	53.4	8.5	21
8	18.6	11.3	62.2	9	11
9	19.2	14.2	72.8	8	14
10	14.2	8.5	69	6	21
11	19.8	14.1	73	8	15
12	20.2	14.6	71.4	9	14
13	22.6	18	71.8	7	11
14	18.3	13.3	73	7.8	10
15	24	18.7	73	6.8	17
16	24.4	19.4	74	7.8	11
17	28.4	24.7	80	8.2	9
18	28.7	25.6	83.2	9	10
19	26.1	22.8	82	6.3	11
20	26.5	23.6	84	6	9
21	27.3	23.9	82	8	12
22	24.3	21.4	84	8	20

*On a scale of 1 to 10, 1 indicates clear skies and 9 indicates total cloud cover. 10 indicates thunderstorms.

Table II. Magnesium Test Panels For Shipboard Exposure.

Ident. No.	Alloy	Treatment
DF1471-3, 4	QE 22	Thin H.A.E. anodize + 2 coats Glyptal-S paint
DF1440-1, 2	QE 22	Thin H.A.E. anodize + Surface Seal* + 2 coats Glyptal-S paint
DF1312-3, 4	WE 43	Thin H.A.E. anodize + Surface Seal* + 2 coats Glyptal-S paint

*Araldite 961 resin applied by dip technique (3 coats) in accordance with MEI DATA SHEET 200A (Ref. 2).

Table III. Evaluation Of Test Panels.

Specimen ID	Material	Description	Corrosion Condition (Summary of 4 Independent Evaluations)
DF 1312-4	WE-43 Mg	SFC Seal + Glyptal	Pitting of Al fitting — no galvanic corrosion discernible
DF 1440-2	QE-22 Mg	SFC Seal + Glyptal	No pitting — looks good
DF 1471-4	QE-22 Mg	Unsealed + Glyptal	Pitting of Al fitting with obvious galvanic corrosion at base of fastener
DF 1471-3	QE 22 Mg	Unsealed + Glyptal scribed	Pitting of Al fitting with galvanic effects at base, but not at fastener; coating at scribe in base severely corroded
DF 1440-1	QE 22 Mg	SFC Seal + Glyptal scribed	Not as bad as DF 1471-3 — corrosion at scribe
DF 1312-3	WE-43 Mg	SFC Seal + Glyptal scribed	Tiny amount of corrosion at scribe — no galvanic effects noted
CONTROL	7075 T6 Aluminum	Step 1/2", 1"	Exfoliation started on mid plane; no corrosion on top plane
CONTROL	7075 T 73 Aluminum	Step 1/2", 1"	No corrosion on top plane; Pitting plus general corrosion on mid-plane

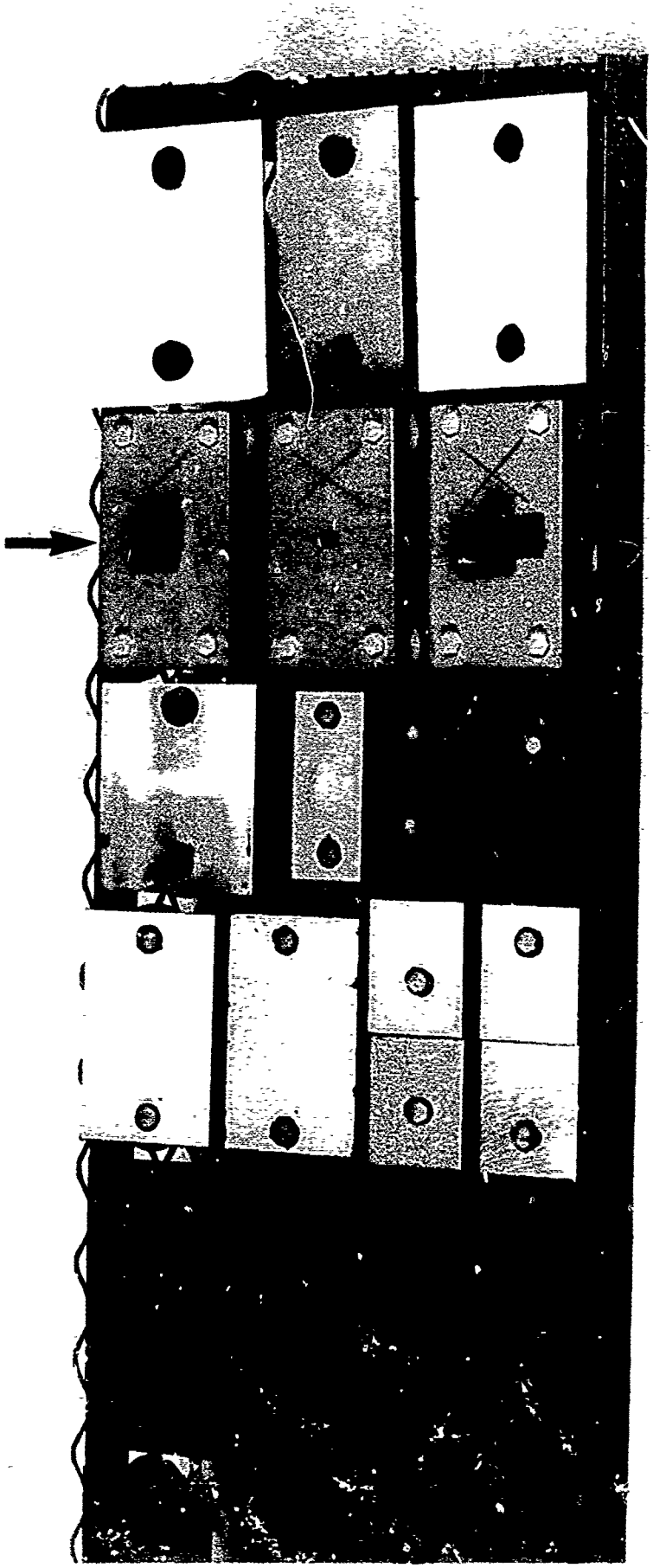

Figure 1. Magnesium Test Blocks Prior To Shipboard Exposure.

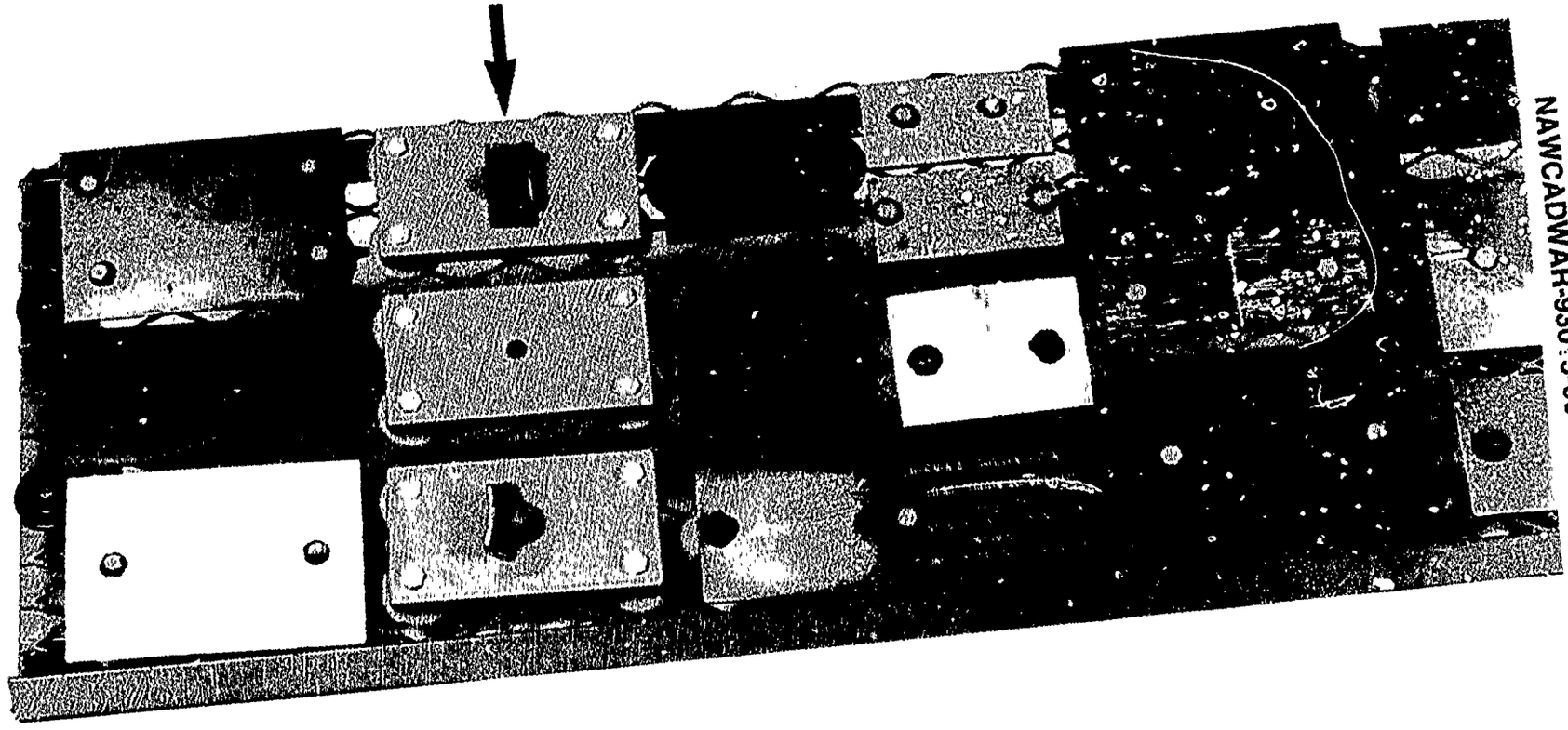

Figure 2. Magnesium Test Blocks Prior To Shipboard Exposure.

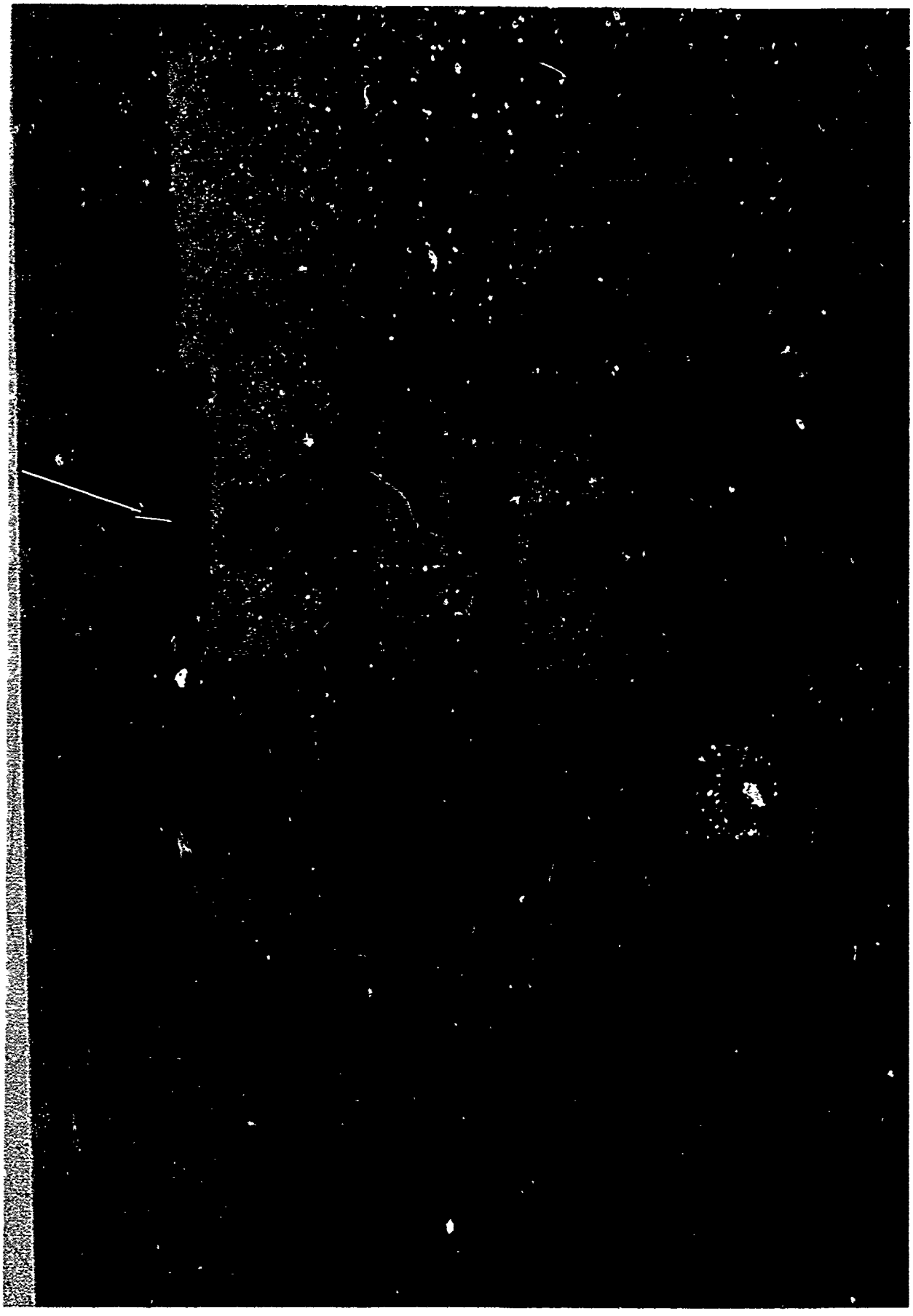

Figure 3. Magnesium Test Blocks After Shipboard Exposure.

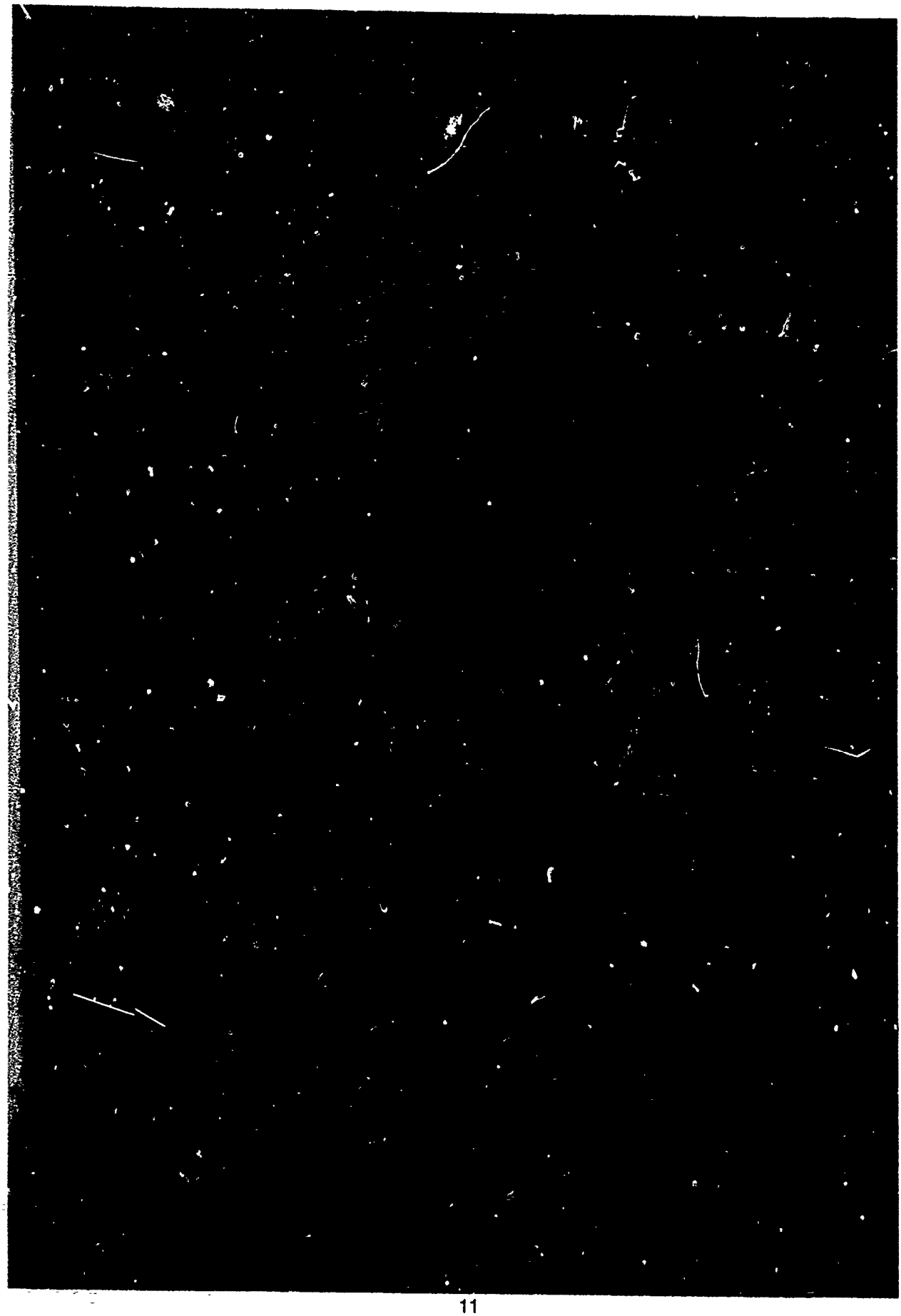

Figure 4. Magnesium Test Blocks After Shipboard Exposure.

Figure 5. Magnesium Specimen DF 1471-3 Unsealed (3X).

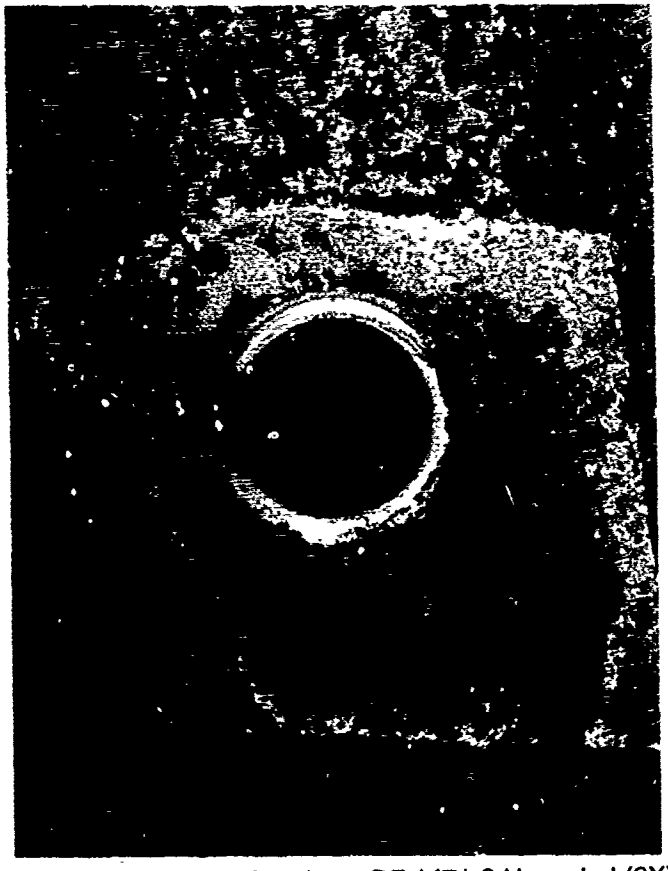

Figure 6. Magnesium Specimen DF 1471-3 Unsealed (3X).

Figure 7. Magnesium Specimen DF 1440-1 Sealed (3X).

DISTRIBUTION LIST (Continued)
Report No. NAWCADWAR-93015-60

No. of Copies

Center for Naval Analysis 1
4401 Fort Avenue
P.O. Box 16268
Alexandria, VA 22302-0268

Naval Air Warfare Center Aircraft Division 2
Lakehurst, NJ 08733
(1 for K. Megerle, SESD Code 5314 KM)
(1 for G. Fisher, SESD Code MT-14)

Metals Information Analysis Center 1
Purdue University
Lafayette, IN

Office of Naval Research
Materials Division, Engineering 1
800 N. Quincy Street
Arlington, VA 22217-5000
(1 for G. Yoder, Code 1311)

Naval Air Warfare Center 6
Aircraft Division Trenton
Box 7176
Trenton, NJ 08628
(6 for Robert Mahonter Code PE-34)

DISTRIBUTION LIST
Report No. NAWCADWAR-93015-60

No. of Copies

Naval Air Systems Command 5
Jefferson Plaza One
Washington, DC 20361-5300
(1 for S. Bettadupur (AIR-5304D))
(1 for M. Dubberly (AIR-5302))
(1 for J. Collins (AIR-5304))
(1 for J. Thompson (AIR-5304C))
(1 for W. Koegel (AIR-5304D))

NADEP Cherry Point 2
Cherry Point, NC 28533-5030
(1 for B. Helms (Code-354)
(1 for Code 340)

NADEP Alameda 1
Alameda, CA 94501
(1 for Code 340)

NADEP Pensacola 2
Pensacola, FL 32508-5300
(1 for O. Hayes (Code 340))
(1 for N. Reeves (Code 342))

NADEP Norfolk 1
Norfolk, VA 23511
(1 for Code 340)

NADEP Jacksonville 1
Jacksonville, FL 32212
(1 for Code 340)

NADEP North Island 1
San Diego, CA 92135
(1 for Code 340)

Defense Technical Information Center 2
Bldg. 5, Cameron Station
Alexandria, VA 22314

Naval Air Warfare Center Aircraft Division 12
Warminster, PA 18974-5000
Attention:
(10 for J. Kozol (Code 6063))
(2 for Technical Library (Code 8131))